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(6) Effect of Aluminum Alloys on Bond Strength

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Report No. 8926-130

Material - Adhesives - Metlbond 4021 (Narmco Resins and Coatings Co.)

Effect of Aluminum Alloys on Bond Strength

Abstract:

The differences between the surfaces of clad 2024-T3, clad 2024-T86 and bare 7075-T6 aluminum alloys caused by variations in heat treatment or alloy composition with respect to adhesive bond strength were observed by means of tests made with surfaces which were primed with Metlbond 4021 primer and joined with AT 10 ~~(Minnesota Mining and Manufacturing Co.)~~ adhesive tape. The results of tensile shear tests at -67°F., room temperature and 300°F., and peel tests at room temperature showed that no significant effect upon adhesive bond strengths occurred from the surface differences indicated.

Reference: Barringer, H. R., Picotte, G. L., Keller, E. E., "Effects of Crystalline Structure of Aluminum Alloy Sheets, As Determined by X-Ray Diffraction, Upon Adhesive Bond Strength," General Dynamics/Convair Report MP 57-983, San Diego, California, 23 October 1958, (Reference attached).

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STRUCTURES & MATERIALS LABORATORIES

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TITLE

REPORT NO. 57-983

EFFECTS OF CRYSTALLINE STRUCTURE OF ALUMINUM ALLOY SHEETS, AS DETERMINED BY X-RAY DIFFRACTION, UPON ADHESIVE BOND STRENGTH

MODEL: MFG. & DEV.
P.R. # 756

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INTRODUCTION:

One of the many variables suspected of contributing to dispersed adhesive bond strengths is the difference in crystalline structures of various aluminum alloys. The differences between various alloys is known, but no evidence indicated a corresponding correlation with adhesive bond strength (Report 9727). Likewise, no information was available concerning possible significant effects of variations in different sheets of the same alloy.

The exact nature of adhesion is not known at the present time. Consequently, it is necessary to investigate various aspects of the problem employing established bond strengths as criteria for significant variations. Standard tensile shear and peel tests are ordinarily used for this purpose. For the present tests, x-ray diffraction and microphotography were utilized in an attempt to discover variations in the structures of the alloys used for bonding. Considerable preliminary work was necessary to establish standard diffraction patterns.

This report discusses only the portions of tests conducted in the Plastics and Adhesives Laboratories, designed to discover possible variations in adhesive bond strengths on various alloys, and on different sheets of the same alloys. Results of x-ray diffraction tests will be reported as an addendum to this report.

OBJECT:

1) To determine the effects of different aluminum alloys upon the strength of metal-to-metal bonds made with Metlbond 4021 adhesive.

2) To determine the effects of various sheets of the same alloys on the strength of the 4021 system.

3) To investigate the use of Promat Proseal #16 conversion coating for comparison with the standard aluminum cleaning procedures employed for these tests.

CONCLUSIONS

Test results indicate that:

1) There is no significant difference in the bond strengths of Metlbond 4021 on 2024-T3 Clad, 2024-T86 Clad, or 7075-T6 Bare Aluminum Alloys.

2) There is no significant difference in 4021 bonds on various sheets of the aforementioned alloys.

3) Promat Proseal #16 is unreliable as an aluminum surface preparation for bonding with Metlbond 4021. However, results of tests with Scotch-Weld AF 10 were more satisfactory.

TEST SPECIMENS

Three sheets of .020" gauge, and three sheets of .064" gauge each, of 2024 T3 clad, 2024-T86, and 7075-T6 bare aluminum alloys were requisitioned from stock, and protected from scratches with a gummed paper coating. The different sheets were marked, and random samples cut from each for x-ray diffraction and photomicrograph tests. Sufficient material from each sheet was then sheared and machined for adhesive tests. Peel specimens, measuring 1" x 9", were obtained from the .020" stock. Tensile shear panels, measuring 4" x 9" were cut from the .064" material. The protective coating on specimens was not removed until cleaning and bonding was begun, in order to protect faying surfaces from scratches.

Tensile shear specimens were made by bonding two 4" x 9" x 064" panels lengthwise with a 1/2" overlap. Individual specimens measuring 1" x 7.5" were subsequently sawed from the bonded panels. Peel specimens were made by bonding two 1" x 9" x.020" strips together flatwise.

Prior to bonding, specimens were vapor degreased in stabilized trichloroethylene. Samples used for alloy comparison tests were cleaned in a sodium dichromate-sulfuric acid solution (FPL Cleaner) composed of 10 parts H_2SO_4, 30 parts H_2O, 4 parts $Na_2Cr_2O_7 \cdot 2H_2O$ as follows:

a. Pre-heat alloys in a distilled water bath for 10 minutes at 150°±5°F.

b. Clean in FPL Cleaner for 5 minutes at 150°±2°F.

c. Rinse in distilled H_2O at room temperature.

d. Dry for 30 minutes at 150°±5°F.

Specimens coated with Promat Proseal # 16 were treated as follows:

a. Pre-heat 2024-T3 Clad alloy in distilled water for 10 minutes at 90°±2°F.

b. Treat specimens for 1 minute at 90°±2°F. in Proseal #16 (Solution of 1 1/2% Proseal 16 AD and 3/4% Proseal 16 BH by volume).

c. Rinse in distilled water at room temperature.

d. Dry for 30 minutes at 150°±5°F. (Exceptions or additions to the foregoing procedure will be noted in Table IV).

Immediately after drying, specimens were sprayed with a single coat of Metlbond 4021 prime, or EC 1290 prime (for Proseal tests with AF10 tape).
All specimens made with the 4021 system were cleaned, primed and baked in one eight-hour period to reduce variables associated with these processes.

Primed specimens were allowed to air dry at ambient temperatures for 15 minutes, and were subsequently baked at 250°F. for 30 minutes. Primed panels were

TEST SPECIMENS (Continued)

wrapped in Kraft paper for storage before bonding.

The Metlbond 4021 and Scotchweld AF10 adhesives employed for these tests were selected from single rolls of tape. Before bonding, a sufficient quantity of tape was desiccated with calcium chloride in a vacuum for 24 hours in order to remove absorbed moisture. Immediately prior to bonding, tape was sandwiched between faying surfaces. Assembled panels were cured for 1 hour at 350°F. with 100 psi pressure in electrically-heated hydraulic platen presses. Two sheets of 1/4" silicone rubber were placed on either side of the entire panels to ensure even pressure over the bond areas.

After bonding, tensile shear specimens were selected randomly for -67°F. room temperature and 300°F. tests, respectively. Peel specimens were tested at +35°F. in a mixture of isopropyl alcohol and dry ice. Tensile shear tests were conducted in a Baldwin-Southwark hydraulic Universal Testing Machine. The -67°F. and 300°F. tests were conducted in an ice box and oven adapted to the testing machine. Specimens were exposed to the test temperatures for ten minutes prior to loading.

RESULTS

Results of tensile shear and peel tests with 4021 tape on various alloys, and different sheets of the same alloys, are shown in Table I - III. Tests conducted with Promate Proseal #16 are described in Table IV.

DISCUSSIONS OF RESULTS AND CONCLUSIONS

Mean values obtained in the alloy comparison tests are unusually consistent. Statistical tests for significance were not conducted, since the standard deviation appeared by inspection to be approximately the same as, or larger than, the difference between means. The consistency of results may be due to very careful control of the bonding procedures, cleaning, favorable atmospheric conditions, or any combination of the above. In any event, the similarity of obtained mean values, plus past experience, indicates that little consistent variation may be expected from the different aluminum alloys ordinarily used for adhesive bonding. This generalization would, however, not necessarily hold true for alloys heat treated at Convair, for instance.

Tests of Promate Proseal #16 were not entirely unsatisfactory. However, it should be noted that increased exposure time in solution results in decreased peel strength. In view of normal shop practice, it would appear that the presently employed conversion coatings are more flexible in this regard. Because of generally unreliable results, the Proseal investigation was discontinued early in the test program.

TABLE I
EFFECTS OF DIFFERENT ALLOYS UPON BOND STRENGTH-METLBOND 4021 ADHESIVE

2024-T-86 Clad Al Alloy

Sample #1

-67°F T.S.	Room Temp T.S.	300°F T.S.	35°F Peel
3100 psi	4960 psi	1520 psi	102 lbs/"/w
2920	4760	1700	102
2900	4920	1500	103
4200	4480	1530	102
2860	4790	1540	100
2900	4600	1500	104
4320	4830	1410	101
2860	4740	1420	101
5200	4760	1700	102
4300	4850	1410	103
2500	4910	1500	Avg. 102
2550	4400	1620	
2570	4660	1860	
2530	4800	1780	
2950	4770	1420	
2750	4870	1560	
Avg. 3218	Avg. 4769	Avg. 1560	

Sample # 2

-67°F	Room Temp	300°F	35°F Peel
4220 psi	4550 psi	1640 psi	100 lts/"/w
1870	4700	1750	102
2780	4640	1400	103
3000	4440	1280	100
2750	4850	1830	101
4760	4750	1610	99
2550	4740	1470	100
3440	3900	1500	105
3130	4640	1480	101
3120	4960	1440	102
3890	5210	1640	Avg. 101.3
3400	5030	1650	
2370	4840	1470	
3500	4620	1630	
3250	4760	1420	
3300	4800	1410	
Avg. 3210	Avg. 4710	Avg. 1540	

TABLE I (CONT)

2024 T-86 Clad Al Alloy (Cont'd)

Sample #3

-67°F T.S.	Room Temp T.S.	300°F T.S.	35°F Peel
2090 psi	4900 psi	1460 psi	101 lbs/"/w
3520	4600	1450	102
5260	5040	1480	100
4280	4950	1550	101
2480	5170	1420	101
4620	4740	1640	102
4400	4960	1490	100
4280	4700	1460	103
2280	5040	1500	104
2820	3760	1460	101
3920	4620	1620	Avg. 101.5
3250	4800	1840	
2200	5000	1280	
2750	4820	1400	
2600	4840	1750	
2700	4700	1640	
Avg. 3340	Avg. 4790	Avg. 1530	

TABLE II

EFFECTS OF DIFFERENT ALLOYS UPON BOND STRENGTH*METLBOND 4021 ADHESIVE

2024 T-3 Clad Al Alloy

Sample #1

-67°F T.S.	Room Temp T.S.	300°F T.S.	35°F Peel
2840 psi	4450 psi	1320 psi	102 lbs/"/w
2760	4950	1300	102
3160	4600	1480	104
3620	4850	1580	100
2000	4950	1220	98
3820	4900	1360	103
4260	5000	1500	101
3940	4400	1760	101
3660	4930	1420	100
2760	4600	1620	105
3120	5060	1480	Avg. 101.6
2580	4950	1640	
3000	4500	1640	
3020	4950	1450	
2920	4650	1460	
3380	5040	1420	
Avg. 3180	Avg. 4800	Avg. 1480	

Sample #2

-67°F	Room Temp	300°F	35°F Peel
2060 psi	5000 psi	1490 psi	100 lbs/"/w
1820	4950	1350	101
2720	4600	1520	101
3160	4700	1360	102
2800	4500	1250	100
3220	5050	1640	100
3280	4650	1310	100
2940	4960	1640	100
4320	4600	1800	102
2340	4800	1740	100
2920	4550	1440	Avg. 100.6
3240	5040	1230	
4660	5180	1700	
3720	4400	1560	
3400	5020	1240	
3420	4820	1520	
Avg. 3110	Avg. 4800	Avg. 1520	

TABLE II (CONT)

2024 T-3 Clad Al Alloy (Cont'd)

Sample #3

	-67°F T.S.	Room Temp T.S.	300°F T.S.	35°F Peel
	3600 psi	4750 psi	1460 psi	102 lbs/"/w
	3300	4320	1380	103
	3180	4830	1540	101
	2720	4440	1660	100
	3040	5060	1300	105
	2520	5090	1260	103
	3000	4260	1560	99
	1950	4900	1500	102
	3300	4910	1420	102
	3000	4700	1540	100
	2700	4960	1780	Avg 101.8
	3000	5100	1380	
	3020	4600	1430	
	3320	4620	1440	
	3100	4500	1580	
	3600	4840	1580	
Avg	3020	Avg 4740	Avg 1490	

TABLE III

EFFECTS OF DIFFERENT ALLOYS UPON BOND STRENGTH-METLBOND 4021 ADHESIVE

7075 T-6 Bare Al Alloy

Sample #1

-67°F T. S.	Room Temp T. S.	300°F T. S.	35°F Peel
2920 psi	4760 psi	1460 psi	102 lbs/"/w
4200	4480	1380	102
2900	4600	1680	101
2860	4740	1620	100
4300	4850	1360	100
2550	4400	1260	103
2530	4800	1660	102
4220	4870	1500	102
3000	4700	1540	102
2750	4440	1530	101
4350	4750	1500	Avg 101.5
3440	3930	1700	
3120	4960	1520	
3400	5030	1420	
3500	4820	1410	
3320	4800	1500	
Avg 3340	Avg 4680	Avg 1500	

Sample #2

-67°F T. S.	Room Temp T. S.	300°F T. S.	35°F Peel
3520 psi	4620 psi	1580 psi	103 lbs/"/w
4280	4950	1460	101
3620	5170	1720	98
4220	4750	1840	101
2820	4960	1220	102
3250	4950	1420	103
2300	4850	1840	101
2600	4900	1500	101
3750	4400	1560	103
2480	4600	1420	102
2760	4950	1780	Avg 101.5
3160	4500	1860	
3820	4650	1620	
3660	5000	1500	
3120	4600	1410	
2580	4500	1700	
Avg 3250	Avg 4770	Avg 1590	

TABLE III (CONT)

7075 T-6 Bare Alloy (Cont'd)

Sample #3

-67°F T. S.	Room Temp T. S.	300°F T. S.	35°F Peel
2720 psi	4960 psi	1520 psi	101 lbs/"/w
3160	4310	1240	102
2800	5040	1520	101
3220	5020	1750	103
3280	4750	1640	102
2940	4830	1310	100
4320	4430	1740	98
2340	5060	1440	99
2920	4260	1260	105
3240	4910	1560	102
4310	4960	1500	Avg 101.3
3720	4600	1420	
3400	4900	1520	
3600	4840	1780	
3380	4750	1430	
3180	4620	1440	
Avg 3280	Avg 4770	Avg 1500	

TABLE IV

TESTS OF PROMAT PROSEAL # 16-ROOM TEMPERATURE PEEL STRENGTH (Lbs./In.)

A. Processed per manufacturer's instructions
Cleaned in Oakite 61A 30 Min. @ 180° F.
Proseal 6 Min. @ 90°F.

	METLBOND 4021	SCOTCHWELD AF10
1.	18 lbs/"Width	53 lbs/"Width
2.	16	50
3.	15	52
4.	15	51
5.	15	50

B. Same as (A) except time in Proseal varied.

	METLBOND 4021	SCOTCHWELD AF10
1 Minute		
1.	60 lbs/inch Width	58 lbs/Inch Width
2.	59	60
3.	60	57
2 Minutes		
1.	53	58
2.	50	53
3.	52	52
4 Minutes		
1.	49	56
2.	47	55
3.	47	51
6 Minutes		
1.	18	55
2.	16	52
3.	18	54

TABLE IV (CONT.)

C. Oakite #34 added to system.

Oakite 61A
Oakite 34-15 Min. @ room temperature.
Proseal (Immersion time varied).

Metlbond 4021

1.Minute

1. 54 lbs/Inch Width
2. 53
3. 54

2 Minutes

1. 45
2. 43
3. 41

4 Minutes

1. 35
2. 28
3. 20

6 Minutes

1. 18
2. 18
3. 17